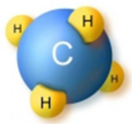
CSG & Geophysics (fundamentals)

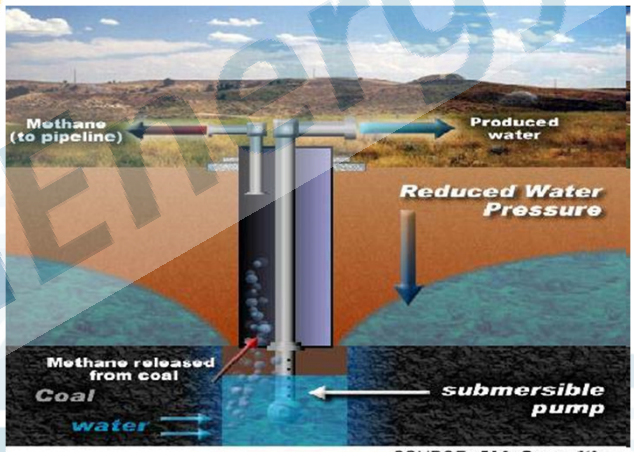
Module 2: Production & Completion, Water, and Others …



Prepared by: Scott Thomson

26th February 2012

The basic principles …its all about depressurisation of the reservoir …



SOURCE: ALL Consulting

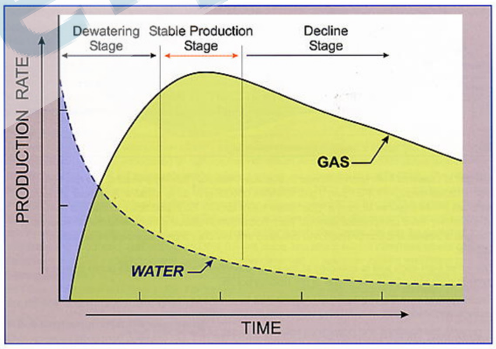
Production & completion methods

- What methods to use? What drives that choice?
- Production challenges
- State of the game in Australia
- Pros and cons of the various methods

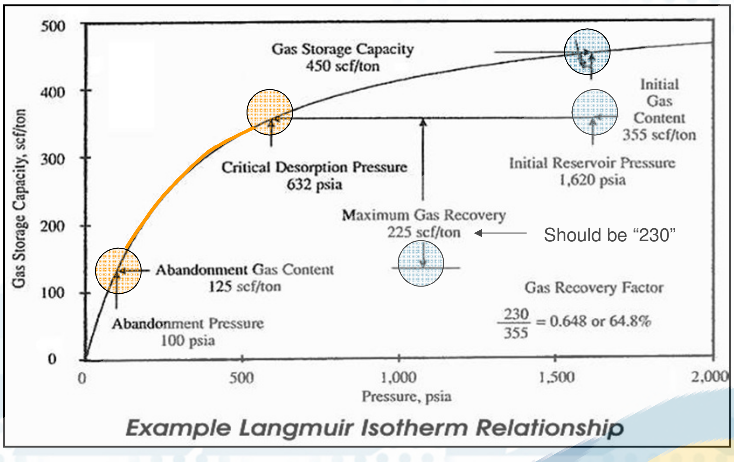
There are a lot of alligators in this swamp …

Key production terms & concepts

- Initial Reservoir Pressure & Gas Content
- Critical Desorption Pressure (CDP)
- Abandonment Pressure & Gas Content
- Recovery Factor
- Water produced
- Gas produced
- Dewatering Stage
- Production Stage
- Decline Stage

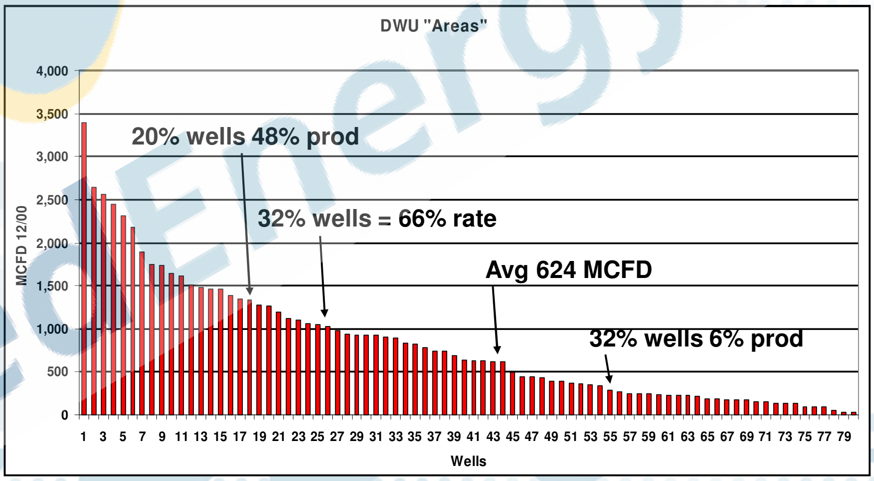


Adsorption Isotherm Recovery Factor

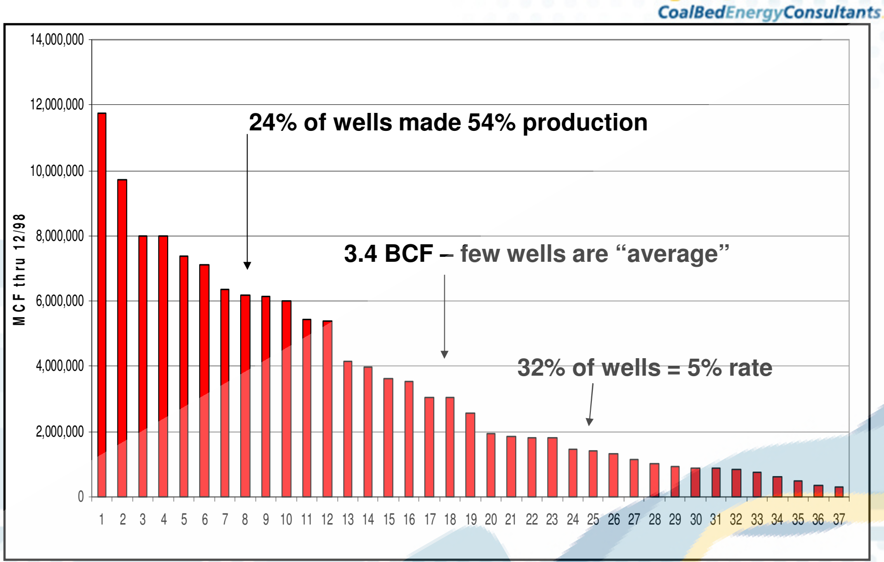


GRI-97/0263 Mavor & Nelson

Drunkards Wash Production Variation



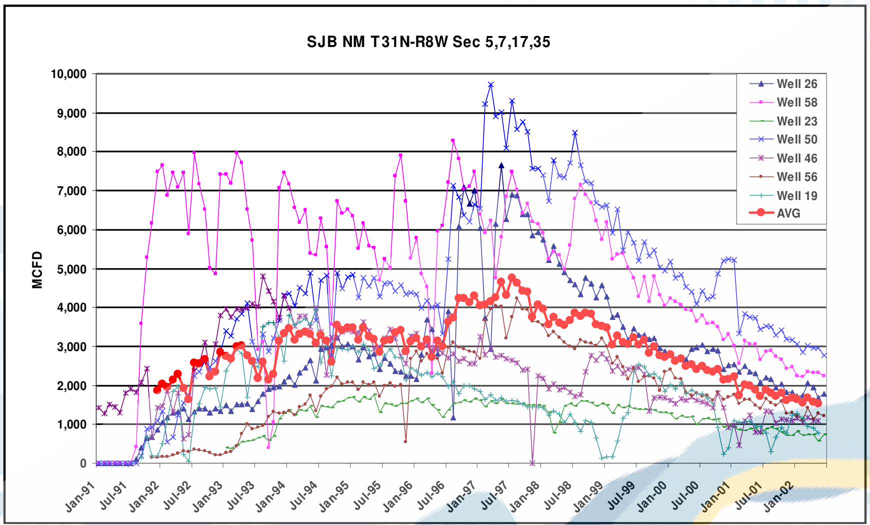
San Juan Basin 32-9 Production Variation



Why does production vary between wells?

- **Interference** – the influence of other wells, development timing
- **Fundamental geology** - coal quality, rank, stress, cleating, mineralisation, coal thickness (net pay)
- **Domain influences** – trapping mechanisms, baffles or barriers?
- **Gas origin** – thermogenic, biogenic or mixed?
- **Fundamental reservoir properties** – relationship between gas content, gas saturation and reservoir pressure
- **Nuances** of drilling, production and completion techniques

Reservoir Variation – SJB 32-9 Unit



Variability is a function of …

- The inherent geological factors.
- The things we do to the well.
  - Choice of production method
  - Damage issues

"Skin"

One we can't do anything much about …
(other than attempt to understand it).
The other is a very important part of CSG, and gets a lot of attention.

Some truisms …

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- All coal of sufficient rank is likely to contain gas.
  - *Governed by rank & burial history; thermogenic gas.*
  - *The 'surprise'; biogenic gas.*
  - *The unwelcome complication;* CO_2*.*
- Even coal of lower rank than "optimum" (for thermogenic gas generation) **CAN** contain gas. E.g. The Powder River Basin (and many Australian basins).

It may be easier to establish favourable "Gas In Place" numbers than to actually produce …

Australian coal basins

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- All the successful CSG plays have been in the Surat or Bowen Basins of Australia thus far.
- What do they have in common?
  - Rank? *Kind of … both are of sufficient rank to contain large quantities of gas, but Surat generally less so than Bowen.*
  - Permeability? *Yes, permeability definitely a factor, and Surat generally more permeable than Bowen.*
  - Gas content? *Yes, good gas contents, with Bowen generally higher than Surat.*
  - Saturation? *Yes, all successful fields are close to saturation.*
- Plenty of other prospective or analogue basins that show promise. *Many of which are wrestling with nuances of production economics.*

Bottom line: GIP not really a problem.

You can establish reserves … but can you produce?

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Types of P & C methods

- Barefoot wells
- Vertical wells with stimulation: hydraulic fracturing & cavitation methods (the "conventional" approach).
- Medium Radius Drilling (MRD) surface to seam.
  - stimulation (?)
- *Tight Radius Drilling (TRD) surface to seam (or a variant).*

Only the first three are proven methods of CSG production

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A few facts about global P & C methods

- 'Trial & error' has driven the choice of methods in the many CSG plays worldwide
- Permeability is the single biggest driver in determining P & C method
- Worldwide, perm is the project killer …
- We are heading towards low perm solutions as an industry … the 'low hanging fruit' has largely gone …
- US methods (fraccing and cavitation in particular) have grown out of success in the San Juan, and may / may not be relevant elsewhere
- Australia has led the charge on the drilling of laterals (MRD SIS etc.)

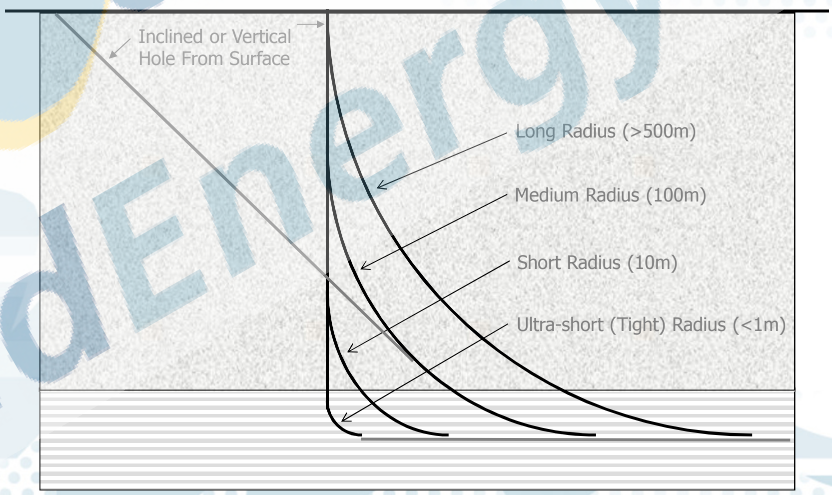
The US experience

- BP has drilled over 1500 wells, Conoco more than 800 in the San Juan

- CNX has drilled 2500 small wells around Virginia (Appalachia)
- In the Powder there are around 17,000 producing wells and about 8,000 shut-in wells making around 1133 MMcfd (!)
- There are around 90,000 CBM wells in the USA … (Palmer, 2010)

Any ideas on the preferred completion method at each site … and why?

Alternative methods of drilling holes from the surface



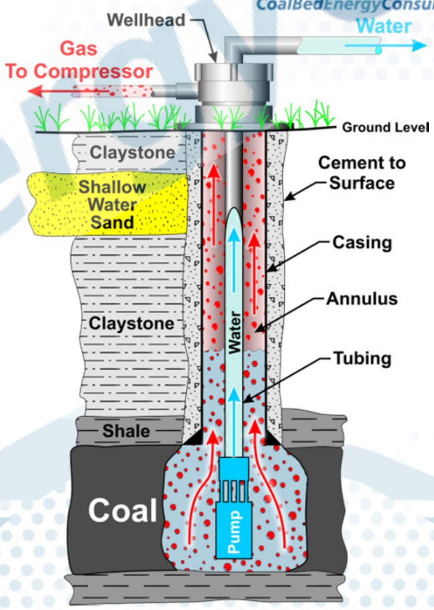
(kindly supplied by CRC Mining)

Bottom line for CSG production & completion strategy

- The cheaper the better … “whatever does the job”.

Barefoot techniques

- Advantages of barefoot completions:
  - Cost
  - Redundancy
  - ‘Cooker cutter’ mentality



Hydraulic Fracturing

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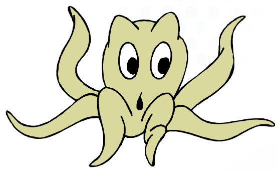

- Hydraulic fracturing, or "fracking or fraccing" has earned a lot of negative media coverage lately ("Gaslands" etc).
- By creating or even enhancing existing fractures, the surface area of a formation exposed to the borehole increases and the fracture provides a conductive path that connects the reservoir to the well. *"These new paths increase the rate that fluids can be produced from the reservoir formations, in some cases by many hundreds of percent."*
- Used primarily in low perm CSG and shale gas applications.

Vertical Well Methods – hydraulic fracturing

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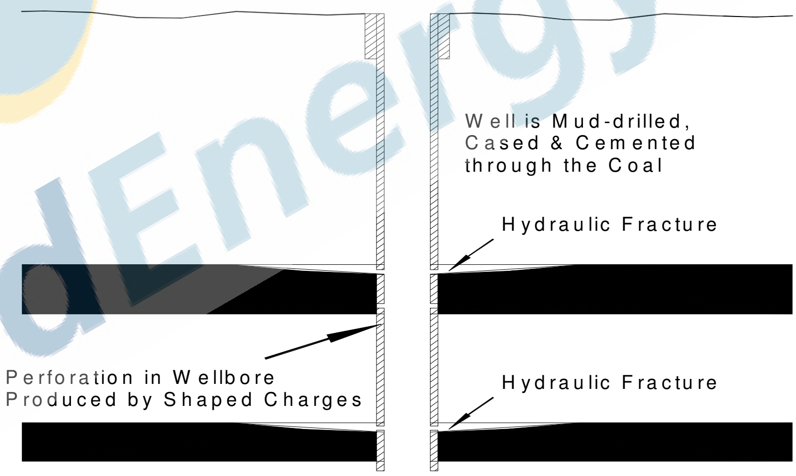

Fracccing Methodology

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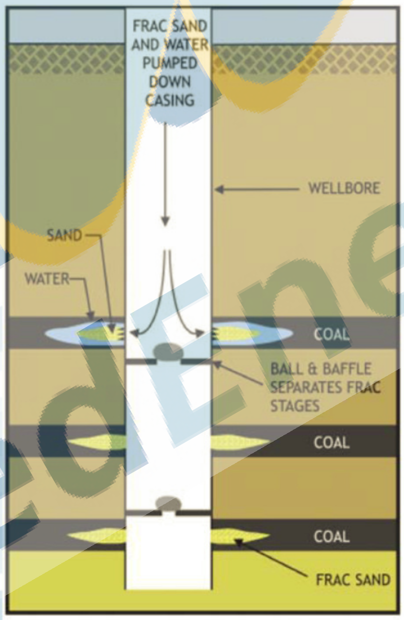
- The fluid injected into the rock can be water, gels, foams, and compressed gases, including nitrogen, carbon dioxide and air.
- 'Eleven herbs and spices' – what chemicals exactly are used?

Is it IP?

- Various types of proppant are used, including sand, resin-coated made ceramics, depending on the type of permeability or grain strength needed. Sand containing naturally radioactive minerals is sometimes used so that the fracture trace along the wellbore can be measured. The injected fluid mixture is approximately 99 percent water, with 1 percent proppant.
- Hydraulic fracturing equipment used usually consists of a slurry blender, one or more high pressure, high volume fracturing pumps (typically powerful triplex, or quintiplex pumps) and a monitoring unit. Associated equipment includes fracturing tanks, high pressure treating iron, a chemical additive unit (used to accurately monitor chemical addition) low pressure pipes and gauges for flow rate, fluid density, and treating pressure. Fracturing equipment operates over a range of pressures and injection rates, and can reach up to 100 MPa (15,000 psi) and 265 L/s (100 barrels per minute).



Source: AGR Oil and Gas Services
2008 Australian CBM—general overview.pdf

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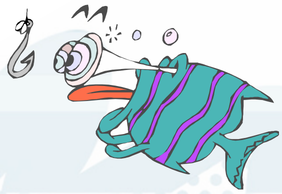
Multi stage fraccing

Key Questions

- Which seams to target?
- How thick should coal be to justify cost?
- Any porous aquifers nearby?
- How big should the frac be?
- What proppant to use?
- What is the stress regime?
- How will the frac interact with face cleat?

General Fraccing Numbers

- Amount of water used per frack - *Generally 1-8 million gallons of water may be used to frack a well. A well may be fracked over 10 times.*
- Amount of chemicals used – *Depends on size of frack. Usually between 80 and 300 tonnes of chemicals used.*



Frac geometry

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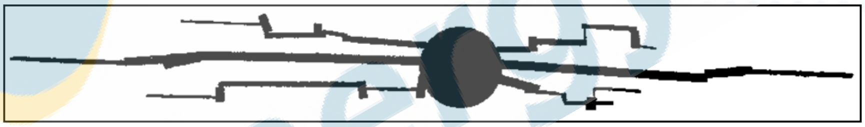
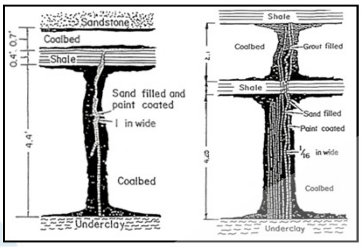
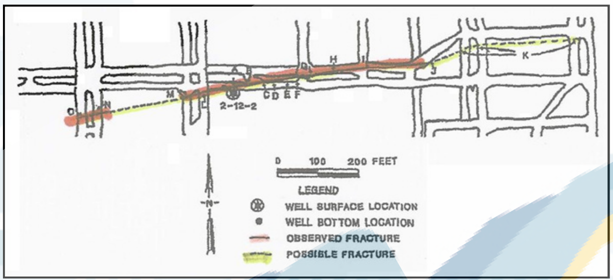


Key Questions

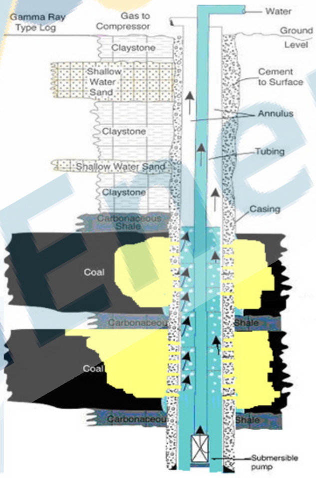
- How long will the frac be?
- Which direction will it go?
- Will it intersect the face cleats?
- Will it close up after time – if so, what proppant?
- Water or gel?

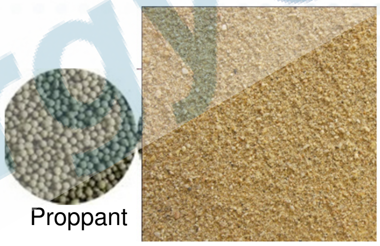
Examples of hydraulic fracturing





Hydraulic fracture completion





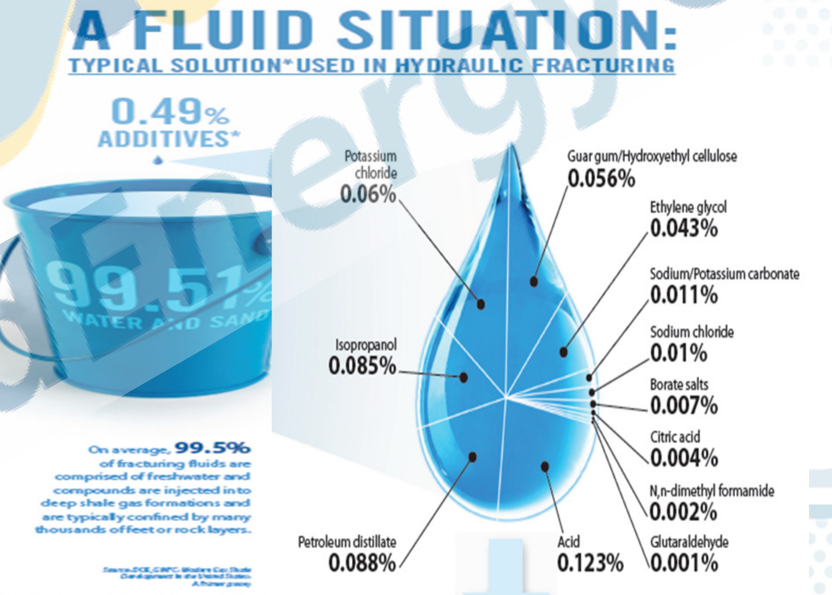
Proppant

- Near well bore connectivity is enhanced
- Frac difficult to control, and difficult to measure.
- Connectivity to water aquifers can be an issue.

Why do People Oppose Fraccing?

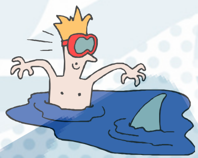
- Fraccing requires massive quantities of water. Hydraulic fracturing in a single well generally uses 2-4 million gallons of water.
- Fraccing injects chemicals (some are potentially toxic) into the ground. Fraccing fluid is largely unregulated (currently the subject of active debate).
- The question of propagation of the fracc into an aquifer …

Chemicals Used



Environmental and Health Effects

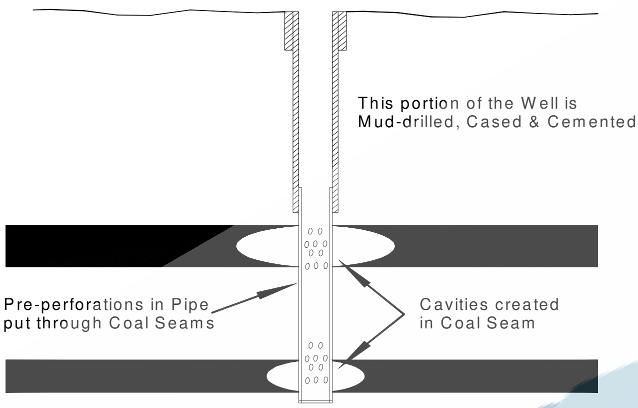
- Include the contamination of ground water, risks to air quality, the migration of gases and hydraulic fracturing chemicals to the surface, and the potential mishandling of waste.
- Arguments against hydraulic fracturing centre around the extent to which fracturing fluid used far below the earth's surface might pollute fresh water zones and contaminate surface or near-surface water supplies.
- The transport, handling, storage and use of chemicals and chemical-laden water can also cause accidents that release materials into the environment, though this does not occur during the hydraulic fracturing process itself.

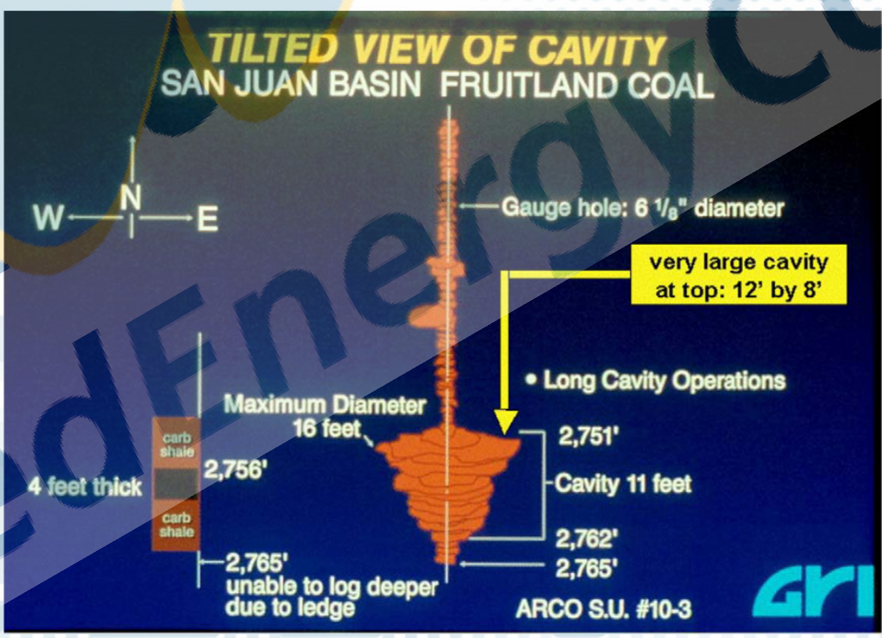


Cavity completion

- Has worked exceptionally well in San Juan Basin, USA and parts of the Comet Ridge, Australia.
- Involves high pressurisation of seam then sudden release of energy … "sounds like a jumbo jet taking off".
- In effect, a stimulated outburst.
- How stable will cavity be long term?
- May damage the coal – in fact, certainly will – but ***has the overall effect enhanced connection of wellbore to natural fracture system?***

Vertical Well Methods - cavitation





Example of cavitation process

Not used that much in Australia …

Key factors in drilling completion strategy

- How many seams to complete?
- Permeability?
- Predictability of coal seam?
- Cost / production trade off?

Most areas work out their own "unique" approach …

Predictability …

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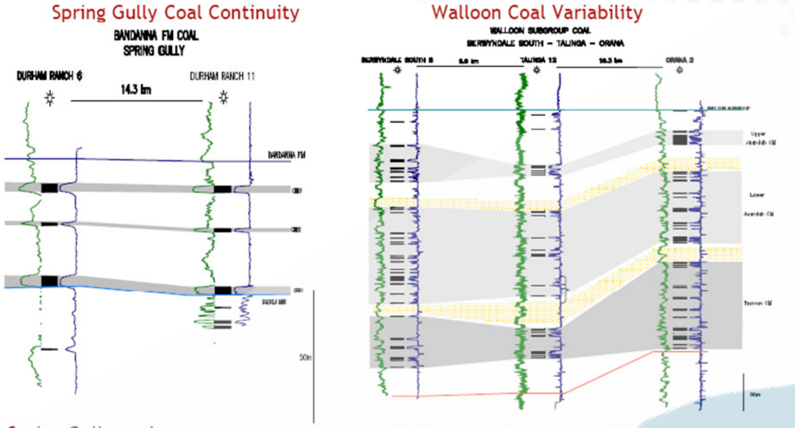
Spring Gully Coal Continuity

Walloon Coal Variability



Spring Gully coal seams are continuous over many ten of kms

Walloons coal seams are thinner and the packages which contain the seams vary in thickness across the area

From http://www.originenergy.com.au/files/NZGasSummit.pdf

"Comingling" … where is the production coming from?

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Zone	Well 1 MCFGD	Well 1 BWPD	Well 2 MCFGD	Well 2 BWPD
Clean Coal	130	0	0	0
Shale				
Clean Coal	30	0	0	0
Dirty Sand				
Shale				
Dirty Coal	80	0	0	0
Shale				
Clean Coal	10	0	0	0
Sand Stringers				
Shale				
Dirty Coal	1300	50		
Shale				
Clean Coal	1200	2700	0	0
Shale				
Beach Sand			0	1500

← Trouble

This the crux of the problem pertaining to aquifers …

Methods of attacking low perm reservoirs

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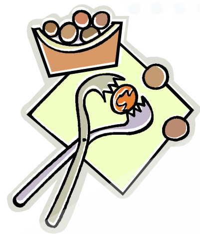

- Medium Radius Surface to Inseam Drilling. (MRD SIS).

Common in Australia – pioneered here, and working very well.

Some MRD SIS layouts – 'conventional'

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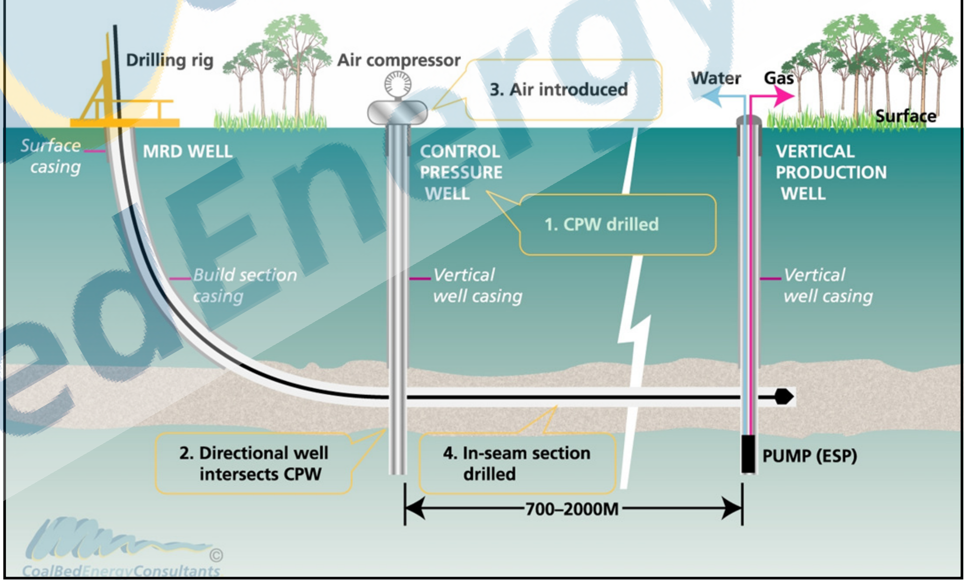
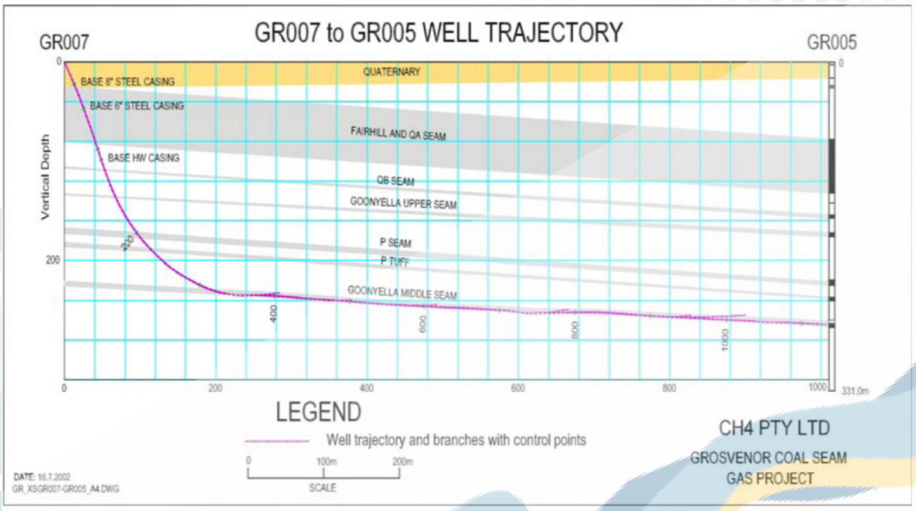
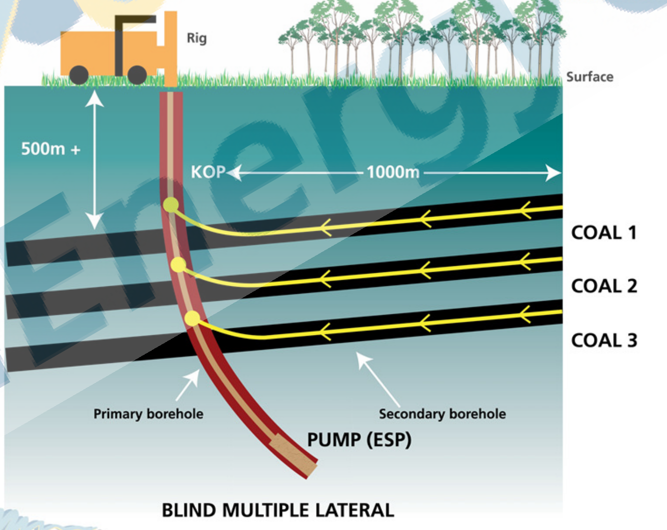


“The Moranbah model”.

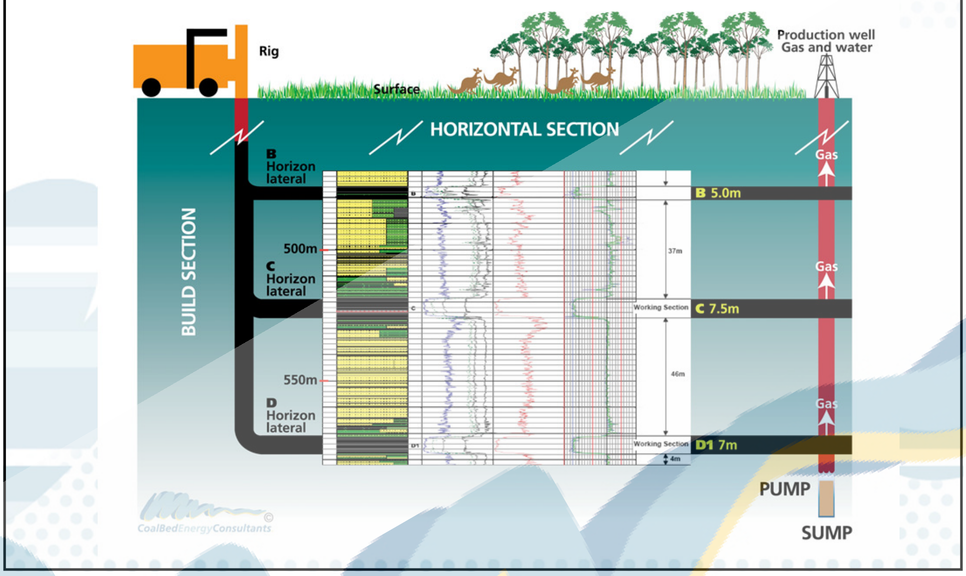


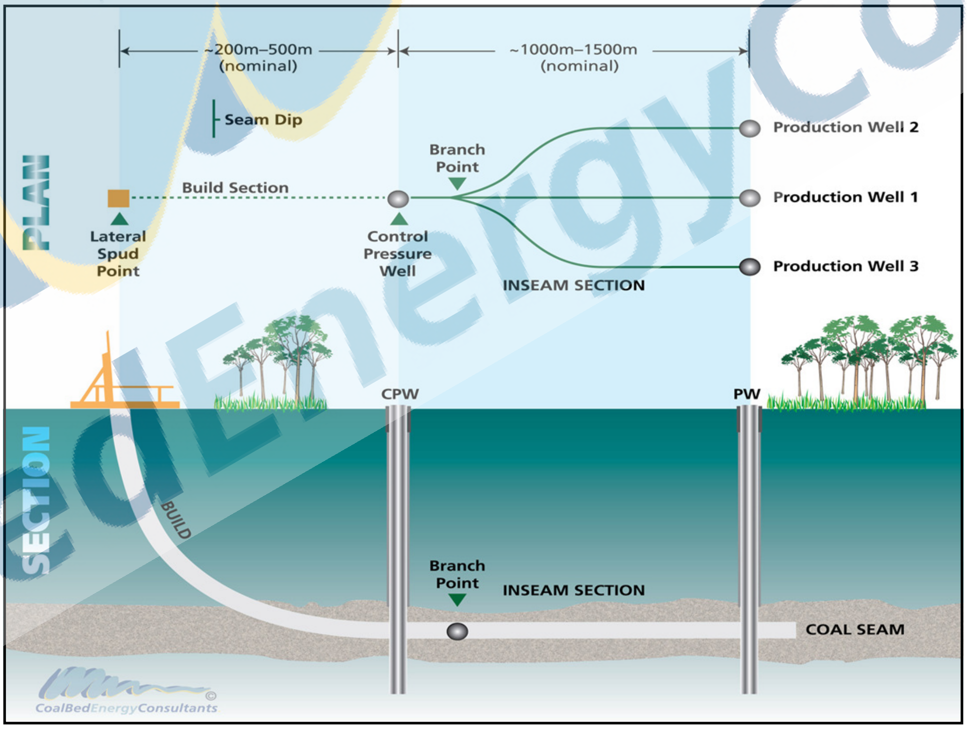
(from Williams, 2004)

The ‘blind’ multiseam SIS well



Multiseam completion to single vertical

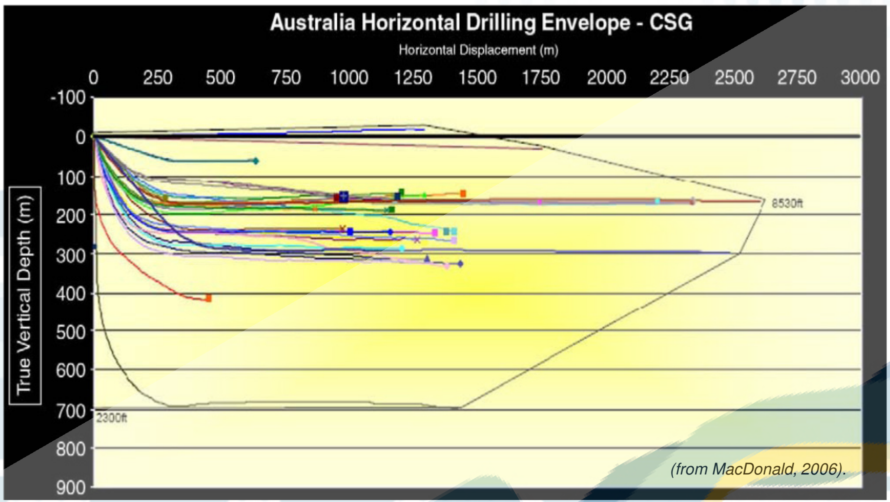




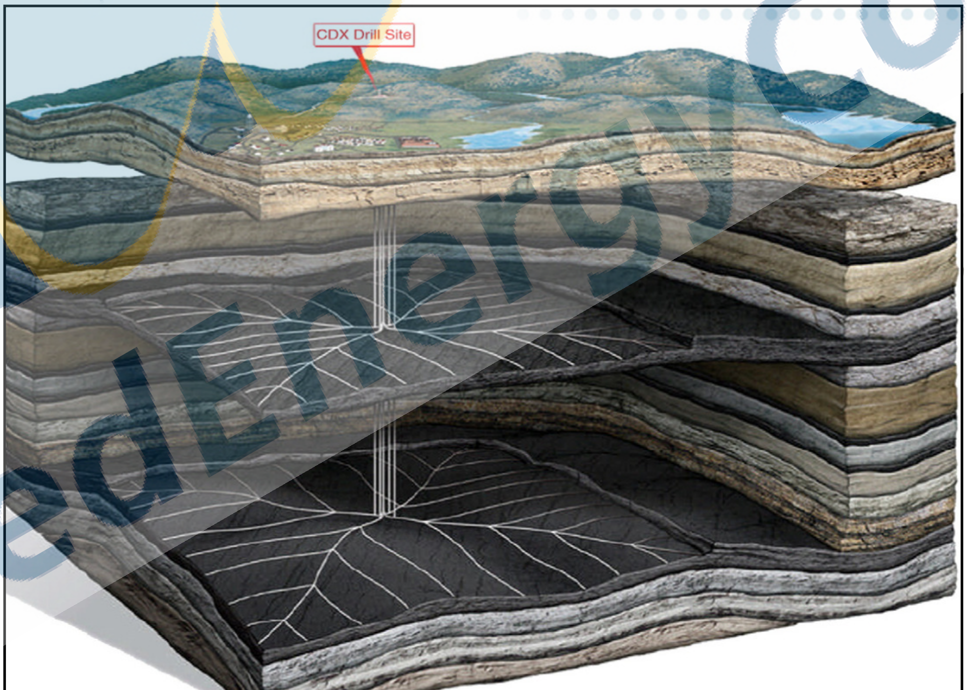
MRD SIS using large 'civil' rigs & oilfield pipe

Approach uses PCD bits

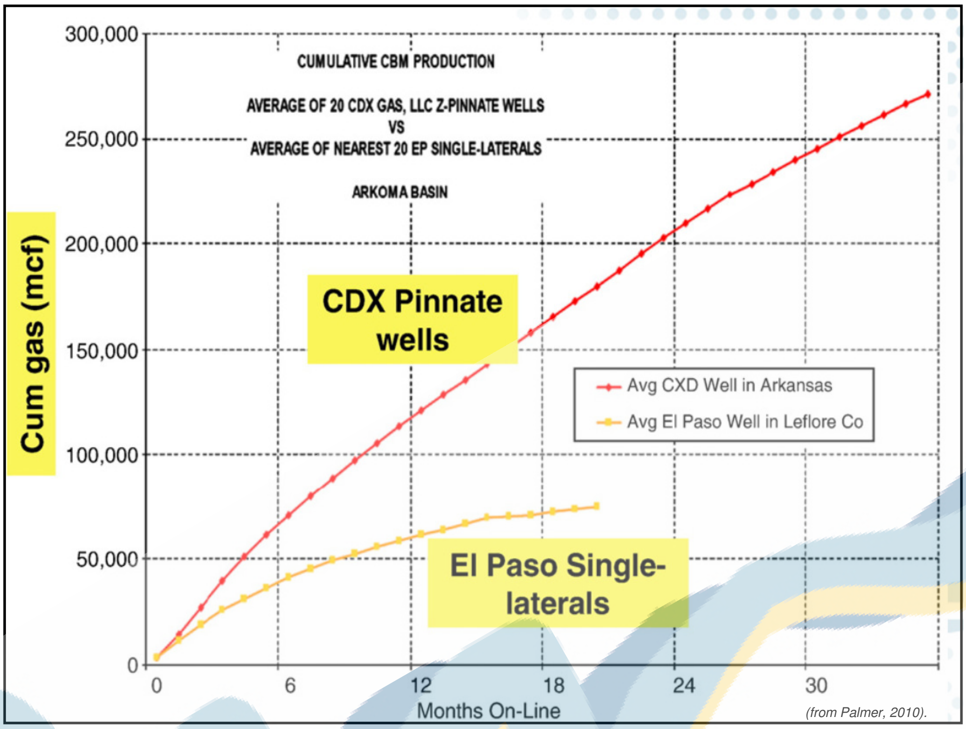
Australian MRD SIS profiles



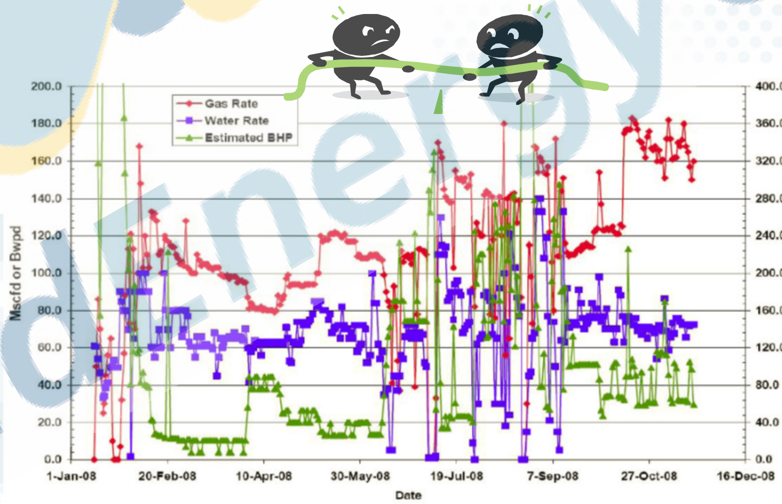
(from MacDonald, 2006).



(from Palmer, 2010, after Spafford, 2007).



MRD SIS Production – Type 1



Notice anything odd about production history ???

MRD SIS Production – Type 2

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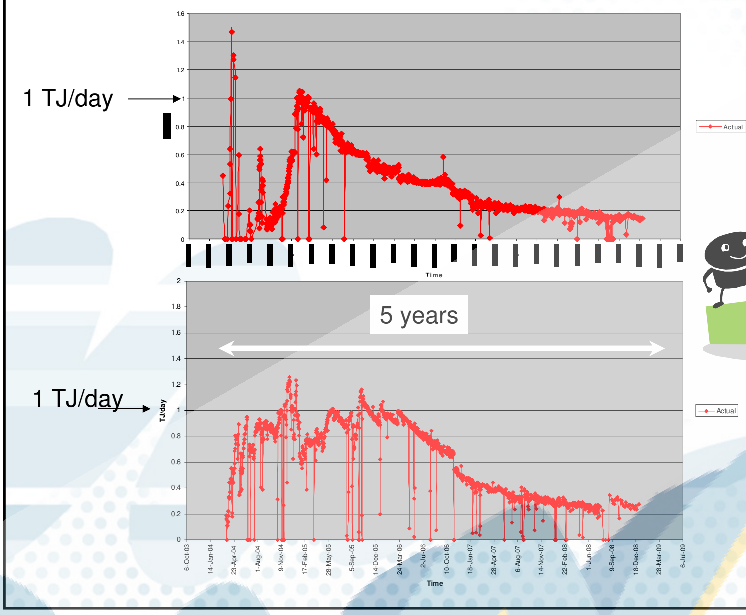

Typical field gathering arrangement

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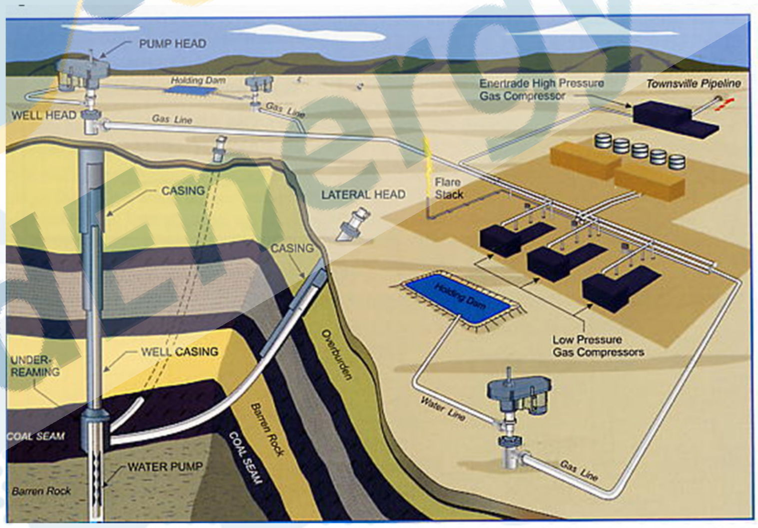

(from CH4 prospectus, 2002)

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In terms of gathering systems & infrastructure …

- What are the advantages of MRD SIS laterals over barefoots?
- In terms of well life?
- Are you aware of any examples of this?

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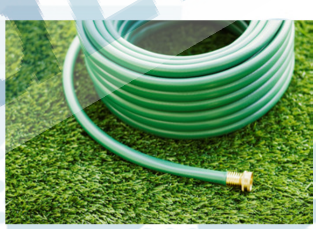
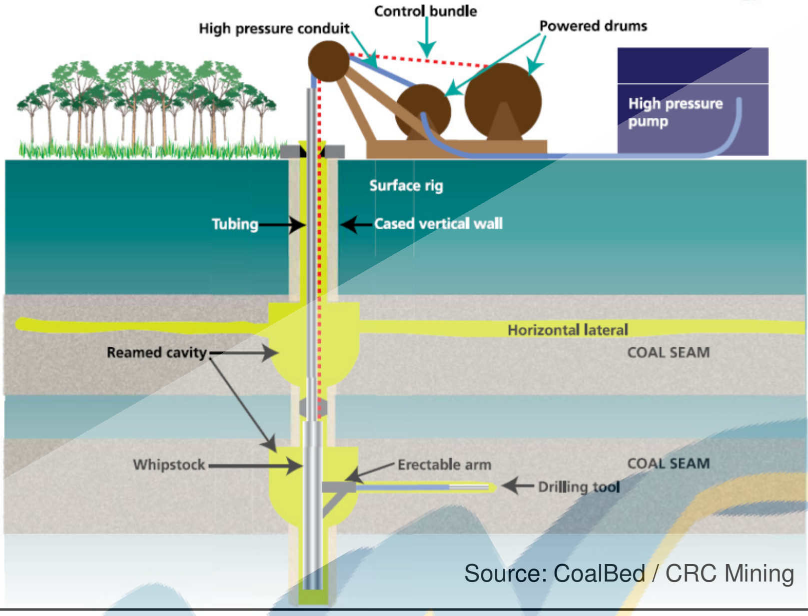
An "out there" solution – Tight Radius Drilling

- Has come from mining – primarily designed for longwall drainage.
- Replicates underbalanced underground drilling from a vertical access point in the seam.
- Has been 10 years + in development.
- Is an interesting twist on the garden hose concept …



Tight Radius Drilling



Source: CoalBed / CRC Mining

Tight Radius Drilling – mechanical arm

(from CRC Mining)

(from CRC Mining)

Tight Radius Drilling – actual results (prior to steering development!)

In summary – what technique will work best for you?

- Depends upon your geology.
  - Multi seam targets?
  - Aquifers around?
  - Coal thickness?
- Depends upon reservoir characterisation issues; permeability, saturation, gas content etc.
- Depends upon commercial drivers!
- Depends upon extent of local opposition to fraccing!

Would you drill amongst the grapes?

This is the heart of "Go to hell AGL" country …

The world according to Palmer …

(see Palmer, 2010)

- Its all about perm …

(I tend to agree …)

- Perms < 3mD: Need multi lateral wells
- Perms 3-20mD: Single laterals or standard fraccs
- Perms 20-100mD: Cavities or SIS or high-perm fraccs
- Perms >100mD: Under-ream or cavities

Any questions about P & C strategy?
How about another exercise …

Now let's talk water …

"Water, water, every where,
And all the boards did shrink ;
Water, water, every where,
Nor any drop to drink.

Day after day, day after day,
We stuck, nor breath nor motion;
As idle as a painted ship
Upon a painted ocean.

The hard questions about water …

- Are all coal seam aquifers?
- Does CSG extraction result in aquifer drawdown?
- Will the coal seam recharge? How quickly?
- Water dumped on surface from a CSG well will eventually percolate through to the aquifer from which it was derived. True or false?
- What is the quality of CSG water? Does it vary?
- Can you irrigate crops with CSG water?
- How is CSG water dealt with now?
- Are there any issues with holding ponds?
- Can CSG water be treated to make it more usable?

CSG water tends to be saline & high in TDS…

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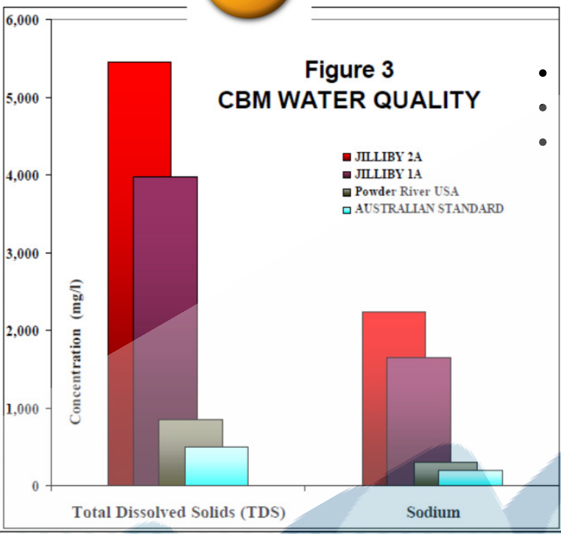

- TDS < 1500 mg/l = fresh
- TDS 1500-5000 mg/l = brackish
- TDS > 5000 = saline

(from Atkinson, 2005)

How salinity can vary through a basin …

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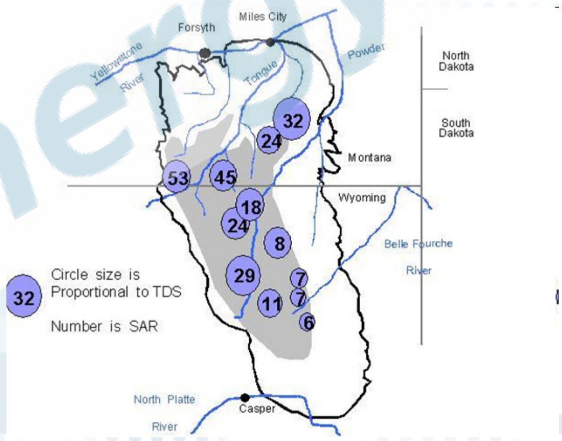
- Any thoughts on why it would vary?



Hydrostatic head & aquifers

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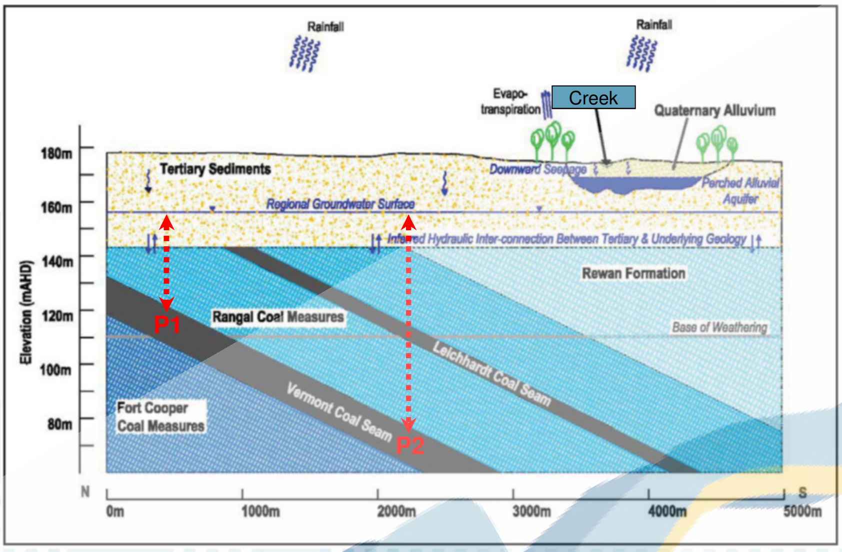

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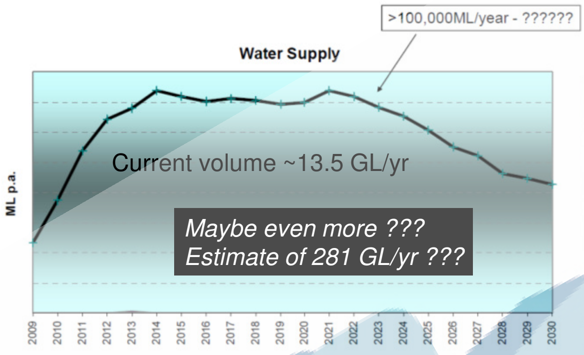
Does this sound familiar … ???

CSG Water

- Why is it an issue?
- What can be done about it?
- Is it an opportunity?

"200-400 ML/PJ, Walloons contain over 30,000 PJ, equates to ~6,000-12,000 GL of potentially co-produced water" … … *Frogtech web site*



(from Grant, 2009)

Qld State Govt Policy

- From discussion paper, "Management of Water produced from Coal Seam Gas production", May 2008.
- ***How can we achieve environmentally sustainable outcomes and maximise the beneficial use of CSG water?***

Responsibility for Treatment and Disposal	CSG producers are responsible for treating and disposing of CSG water.
Standard for Treatment	All CSG water that is not able to be directly injected underground or used in its untreated form, must be treated prior to disposal or supply to others. The cost of treatment will not be subsidised by the govt.
Use of Evaporation Ponds	Use of evaporation ponds as a primary means of disposing of CSG water is to be discontinued. However, the govt recognises that evaporation and storage ponds will be required for brine disposal and as balancing storages. Existing ponds must be remediated by 2012.
Storage facilities – Design and Operation	Evaporation ponds necessary for water aggregation and storage of brine from treatment facilities must comply with the standards developed by the EPA.
Water Management Plans	A CSG water management plan will be required as part of the environmental plan required to apply for a level 1 environmental authority.
Industry Consultation	Submissions from producers closed on 1 June 2009. Govt sought industry feedback on the circumstances in which industry would co-operate to develop and fund a CSG aggregation and disposal system.

(from Qld Govt, & Bruton, 2009)

Water in the ground

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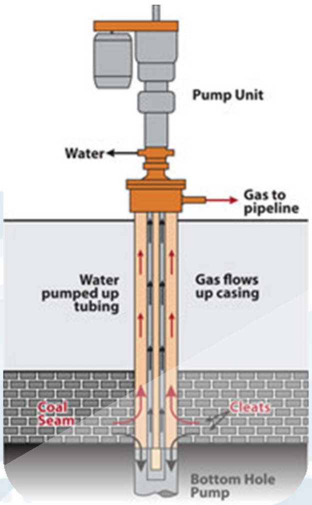
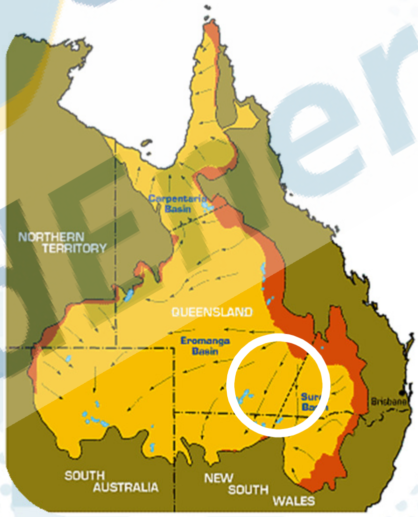


Water in the ground

CoalBedEnergyConsultants



- What is the Great Artesian Basin?
- Why do people care?
- And what's it got to do with CSG operations?

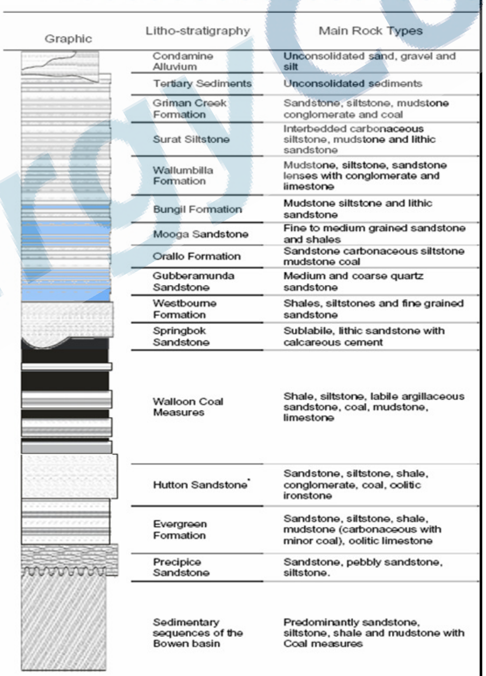
The Surat Basin

- Forms part of the GAB.
- Most of the aquifers (Mooga, Gubberamunda, Springbok, Hutton and Precipice Sandstones) are used for pastoral activities and town water supply. ***Springbok is likely to be in hydraulic connection with Walloons.***
- The Surat is overlain in part by the sediments of the Murray Darling Basin, notably the Condamine Alluvium – ***the Walloons subcrop a significant part of the Condamine Alluvium.***

- Current GAB groundwater use … 549 GL/yr, with 323 GL/yr recharge.
- Estimated water produced from CSG operations … 281 GL/yr (QGC, Santos, AP LNG combined).

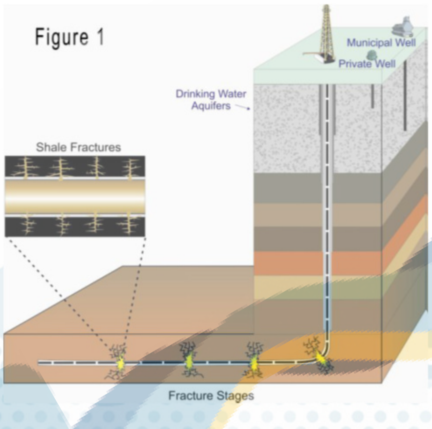
The Walloons & aquifers

- Contained between Cadna-owie – Hooray Aquifer & Hutton SS aquifer
- What will be the effect of extracting H_2O and reinjecting ???
- *"could result in contamination of commercial aquifers by low quality groundwater, decrease in artesian pressure within these aquifers and/or interference of important GAB spring complexes such as the Springsure and Bogan River Groups. In addition, there could also be effects on the head waters of the Murray-Darling Basin" (Frogtech website).*

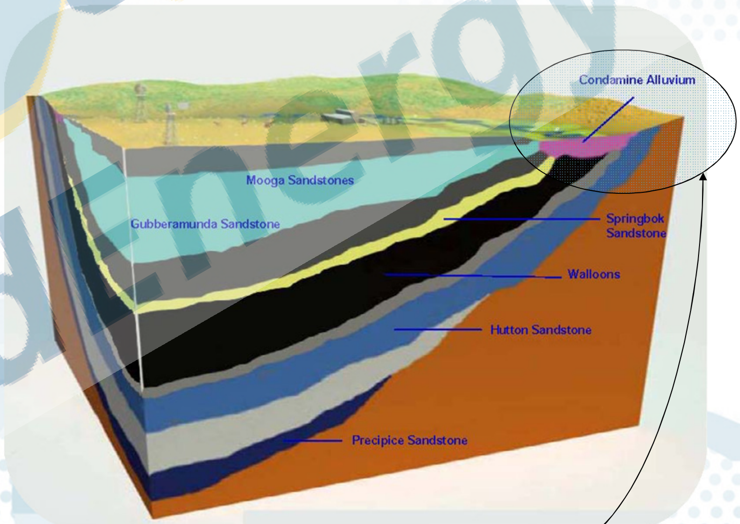


What about fraccing?

- Not all wells will be fracced.
- If they are, the frac should stay within the coal seam.
- ***However,*** if the area is sufficiently depressurised then the possibility of vertical connection exists.



Water in the ground



This is the controversial part …

Water in the ground: a coal measure in 3-D

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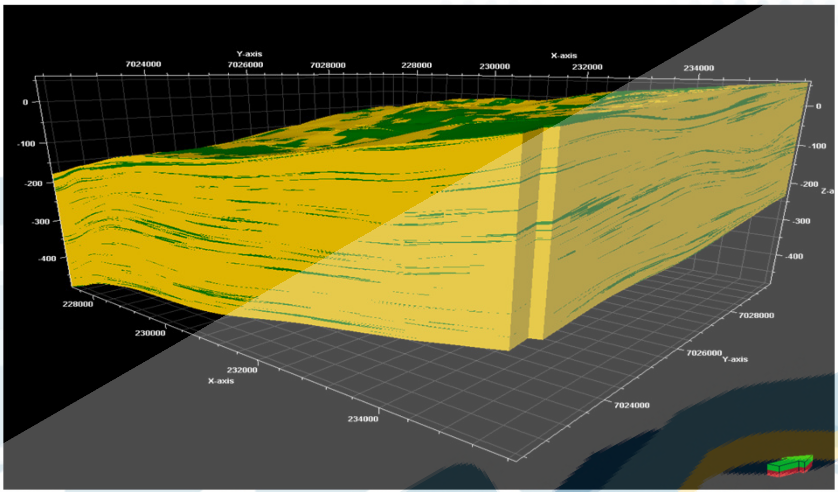

Are coal seams continuous and connected?

Water in the ground

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What about the vertical connections …???

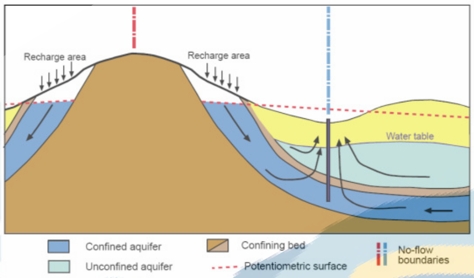
What coal seams look like in outcrop …

Character of CSG water

- pH 8.6
- "Hard" water
- TDS 2,000 – 10,000 mg/L
- Predominantly NaCl (Sodium Chloride), (60-80%)
- Total Suspended Solids 1-700 mg/L (coal fines, clays)

(from Cameron, 2009)

Which is saltier? Biogenic or thermogenic gas play?



(from Scott and Hamilton, 2006)

The Surat

- Producing ~ 13.5 Gl/yr now.
- Expect 100 Gl/yr + with LNG plant developments.
- If stored in evaporation ponds, CSG water over 30 years would be equivalent to the entire surface area of Wivenhoe Dam at full capacity.

(from Qld Govt Discussion paper, May 2009, and Dale, 2009)

EPA rules may be a barrier for reuse

- EPA regulations prescribe how to deal with "saline effluent wastes", and "regulated waste".
- If water to be used for drinking, then quality assurance an issue.

Key commercial issues pertaining to commercialisation

- Well performance variability – reliability of supply.
- Reliability of production performance predictions.
- Linkage to the ebb and flow of gas price.
- Wells fail – delivery assurance.

From perspective of CSG operators water is a bi-product and a "cost of doing business"

"Water is to CSG producers what CSG is to coal miners" …

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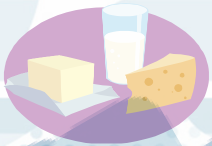
Water quality issues

- Highly variable between wells, and between areas. *CSG water is not all the same.*
- How to isolate poor performers – difficult to engineer & costly. *You get all the production of water, good or bad.*
- Health risks need to be adequately assessed.



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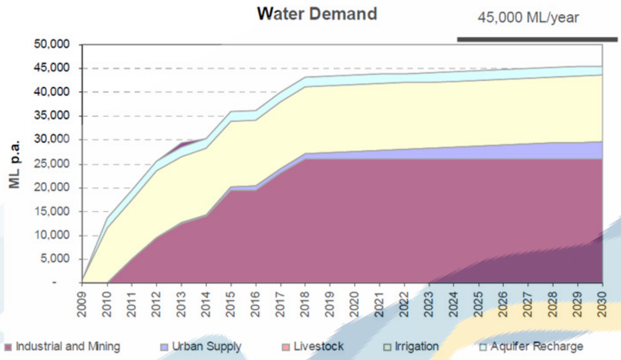
Liability issues

- Disposal of untreated water on soil, water courses etc. *CSG water is "industrial waste".*
- Risk of sabotage, and escape of contaminates.
- Disposal & rehabilitation. *Salt.*

What can we do with it?

- Potable water supplies.
- Partial treatment & utilisation for certain agricultural types. e.g. cotton
- Feedlot use.
- Coal washeries.
- Reinjection.
- Aquaculture.
  - *(Forests of gums).*

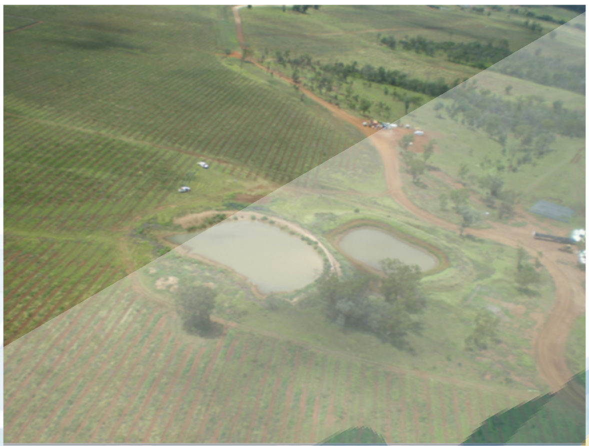


(from Grant, 2009)

Feedlots & dams

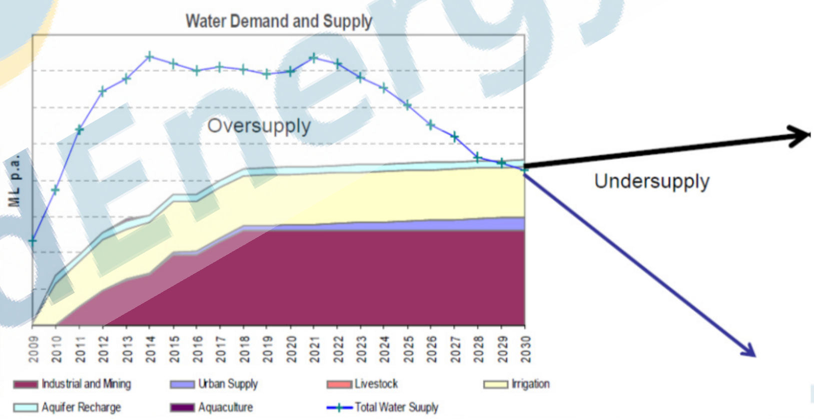
(from Winders, 2009)

Chinchilla White Gums



(from Wilson, 2009)

We'll have more water than we use … and is it sustainable?



(from Grant, 2009)

Issues

- Matching peak production with ongoing demand.
- The significant spatial separation between supply nodes and demand nodes.
- Sustainability and consistency of supply.
- Quality, of course.
- Managing brine.
- Cost. The water costs more to treat than it is commercially worth.

(Saline water leaking from pond, from Wilson, 2009)

(RO plant, from Wilson, 2009)

What do we do with it now?

- Largely unused.
- On site evaporation ponds the main disposal mechanism. *(Range in size from 1 to 100 hectares).*
- Salt (brine) is left behind.
- Rehabilitation involves capping the dams. *Considered 'safe' but not the best application of recycling processes.*
- ***Some water is reinjected, and some is discharged into river systems.***

(from Bruton, 2009)

What do you think we should do with it?

Large evaporation pond

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(from Wilson, 2009)

Evaporation ponds need to be monitored & controlled

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- Leaking pond = bad publicity
- Leaking pond = possibly expensive rehabilitation
- Leaking pond = ammunition for anti CSG lobby

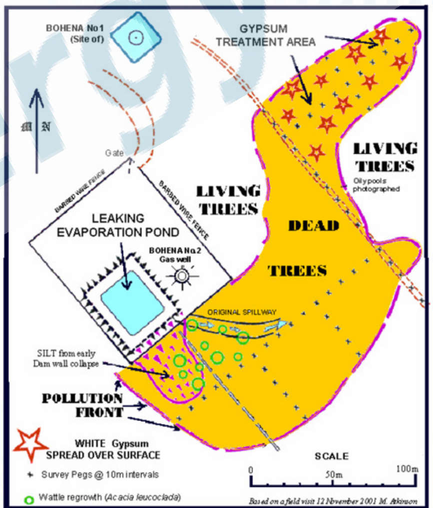

Figure 4
SUBSOIL POLLUTION at BOHENA No 2 WELL-SITE, PILLIGA, NSW

(from Atkinson, 2005)

Lots of water to dispose of …

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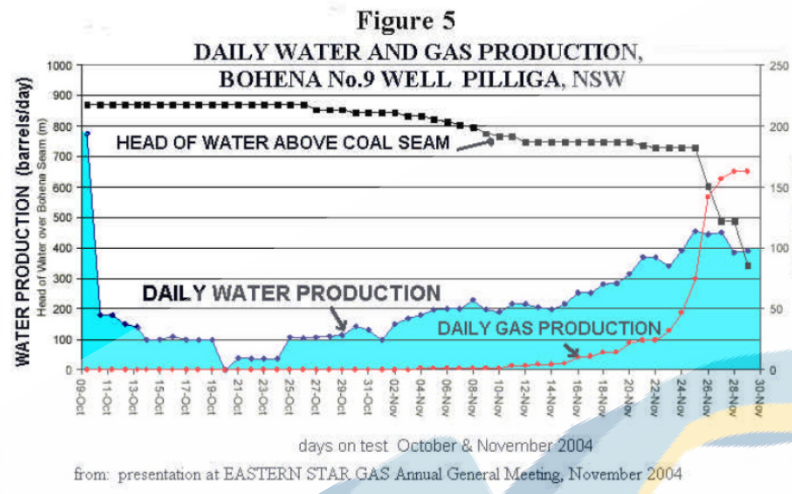

(from Atkinson, 2005)

Beneficial usage : town water

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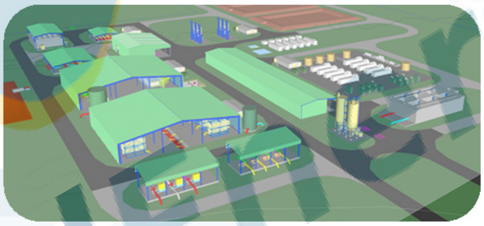
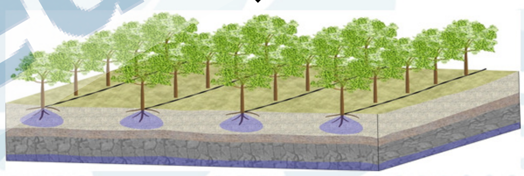


- Central and southern tenements – **industry and town use**
- Northern tenements – **forestry**



Salts

- Preferred option is to harvest salts
- Successful laboratory trials
- Process to determine commercial application

Completing the cycle – reinjection into sandstones or coal

Main concerns

- Long term legacy of salt loaded evaporation ponds.
- Groundwater & landscape impacts of CSG.
- Does current regulatory regime adequately facilitate development of beneficial uses for CSG water?

(from Wilson, 2009)

But main problem is …

- What the CSG process does to the long term groundwater supplies of the GAB.
- ***… " recovery will take in the order of 1,000 years".*** *(Water Group study, 2010)*

Geoscience Australia said the "overriding issue in CSG development is the uncertainty surrounding the potential cumulative, regional scale impacts of multiple developments".

What is UCG & how does it compare to CSG?

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UCG technology does not directly affect natural groundwater reserves

- Groundwater quality is preserved by operating the gasification process below the hydrostatic pressure. The UCG process does not need to pump groundwater to the surface and does not use any kind of "fraccing" process.
- Maintaining the surrounding groundwater pressure acts as containment for the gasification process and ensures that the product gas, "syngas", flows to the surface under pressure via the Production Well.

UCG is able to produce 20 times more energy from the same coal resource than what's possible from CSG

- Not only does UCG have a much smaller environmental footprint than CSG - UCG also delivers maximum value from Australia's natural resources.

Pumping groundwater to the land surface is necessary for gas to be extracted using CSG techniques which may include "fraccing"

- CSG requires lowering groundwater pressure in order to promote gas flow.
- Because the gas is trapped beneath rock and overlying groundwater, this process relies on releasing the water pressure to release the gas (methane).

(parts paraphrased from Carbon Energy web site)

More …

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It has been publicly reported that in the Surat Basin, the CSG process extracts around 260 Megalitres of water (enough to fill about 100 Olympic swimming pools) for every PJ of gas

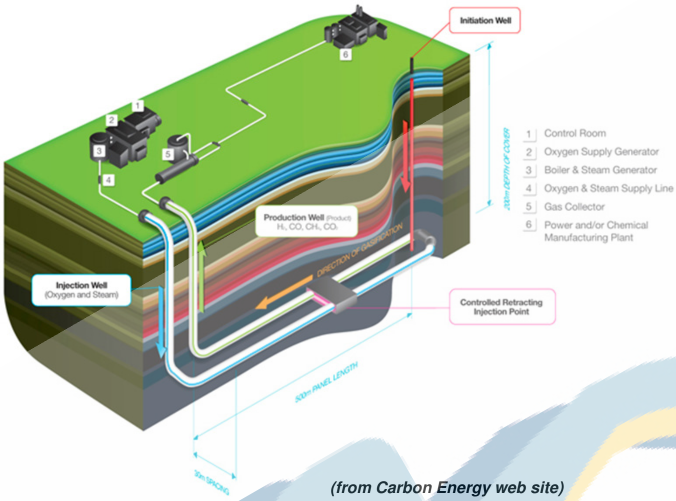
- These significant quantities of saline water are extracted from underground and brought to the surface for treatment.

CSG recovers gas out of the coal seam without utilising the energy in the coal itself

- Following CSG production the energy contained within the coal itself cannot be harnessed using UCG technology until natural groundwater pressure is restored.

(parts paraphrased from Carbon Energy web site)

What does it look like?



(from Carbon Energy web site)

Any down sides?

- Yes – environmental concerns.

Contamination concerns shut Cougar pilot underground gas project
Friday, 16/07/2010
The Queensland Government has shut down a trial of new energy-generating technology, after fears water has been contaminated.
Three companies have been told to review their trials of a process called 'underground coal gasification'.
Some local farmers are saying the move has vindicated their concerns.
ABC News, 16/7/2010

Company disputes significance of "contamination"

End of P & C, water talk … I hope you have learned something useful …

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"I'm thinking about production and completion theory …"